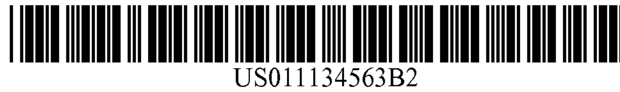
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Noguchi

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(45) **Date of Patent: Sep. 28, 2021**

(54) **OPTICAL MODULE AND METHOD FOR MANUFACTURING THE SAME**

(71) Applicant: **Lumentum Japan, Inc.**, Kanagawa (JP)

(72) Inventor: **Daisuke Noguchi**, Kanagawa (JP)

(73) Assignee: **Lumentum Japan, Inc.**, Kanagawa (JP)

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**

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H05K 1/11	(2006.01)
H05K 1/14	(2006.01)
H05K 1/18	(2006.01)
H01R 12/59	(2011.01)
H01R 12/62	(2011.01)
H01R 12/73	(2011.01)
H04B 10/00	(2013.01)

(Continued)

(52) **U.S. Cl.**

CPC ***H05K 1/025*** (2013.01); ***H01R 12/62*** (2013.01); ***H05K 1/113*** (2013.01); ***H05K 1/118*** (2013.01); ***H05K 3/363*** (2013.01); *H04B 10/50* (2013.01); *H04B 10/60* (2013.01); *H05K 2201/0919* (2013.01)

(58) **Field of Classification Search**

CPC ... H05K 1/02; H05K 1/11; H05K 1/14; H05K 1/18; H05K 1/025; H05K 1/113; H05K 1/118; H05K 1/148; H05K 3/363; H01R 12/59; H01R 12/62; H01R 12/73

USPC 361/749, 752, 760, 826; 174/251, 258, 174/261, 262, 264; 235/454, 462.2; 385/92; 439/61, 65, 79, 629; 1/1

See application file for complete search history.

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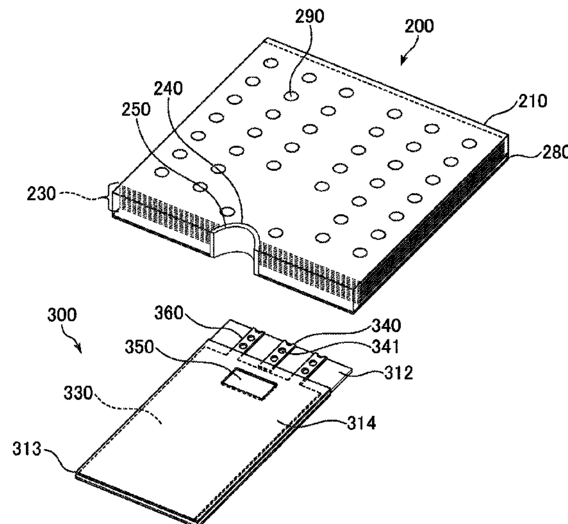
Primary Examiner — Xiaoliang Chen

(74) *Attorney, Agent, or Firm* — Harrity & Harrity, LLP

(57) **ABSTRACT**

A printed circuit board includes a first transmission line provided on an insulating base, a first ground conductor, a notch portion that exposes a part of the first ground conductor, a conductor provided in the notch portion and electrically connected to the first ground conductor, and a first electrode exposed on a main surface of the insulating base facing a flexible board and electrically connected to the first transmission line. The flexible board includes a second transmission line provided on an insulating sheet, a second ground conductor, a second electrode exposed on a main surface of the insulating sheet facing the printed circuit board and connected to the second transmission line, and a third electrode exposed on the main surface of the insulating sheet and connected to the second ground conductor. The conductor and the third electrode are connected by solder.

10 Claims, 13 Drawing Sheets



(51) **Int. Cl.**

H04B 10/50	(2013.01)
H04B 10/60	(2013.01)
H05K 3/36	(2006.01)

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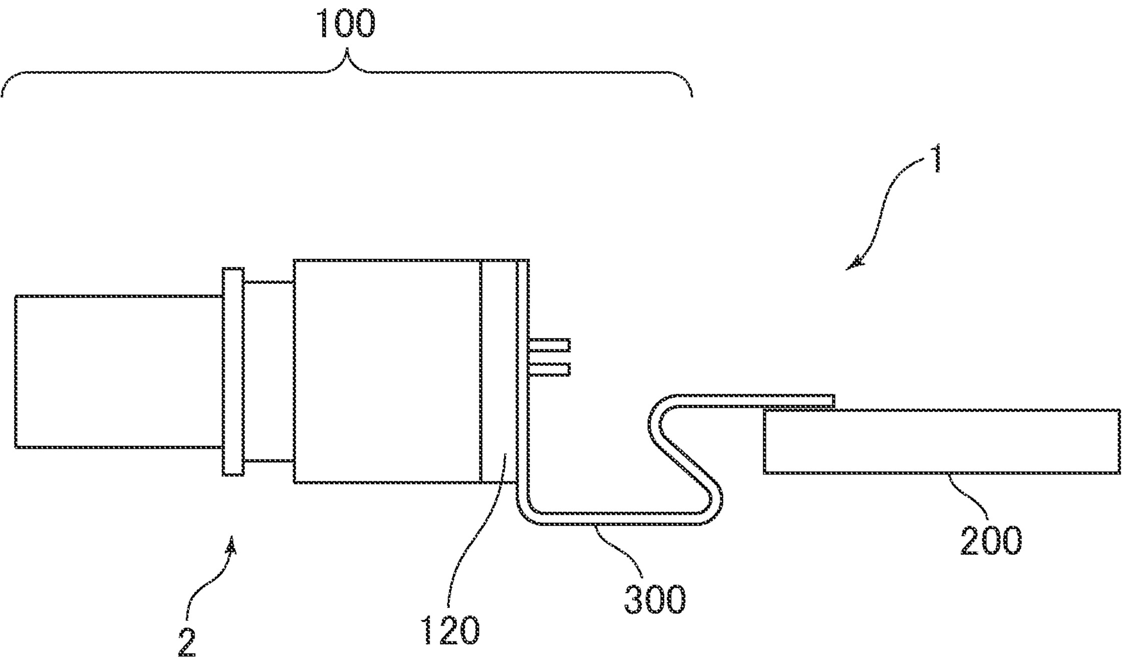
FIG.1



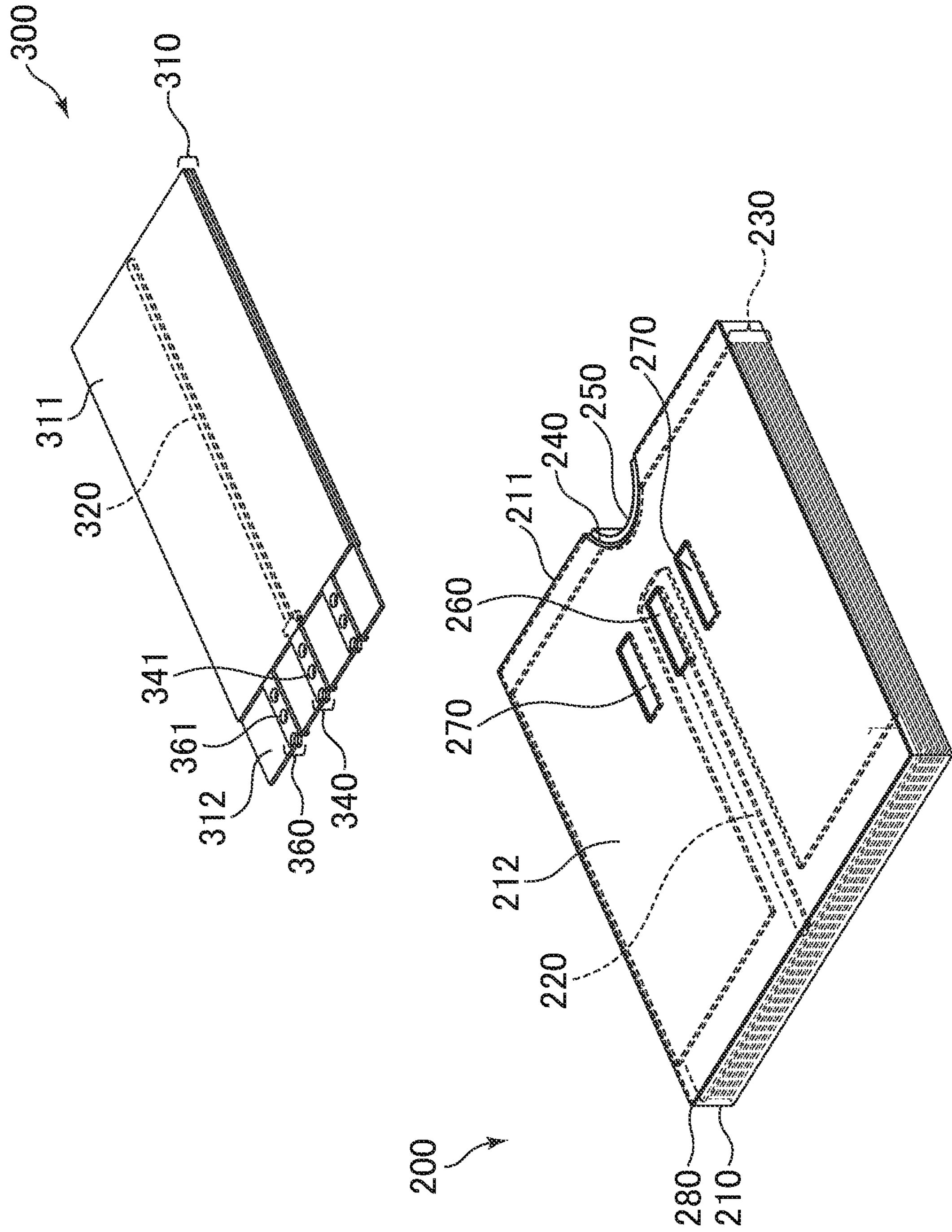
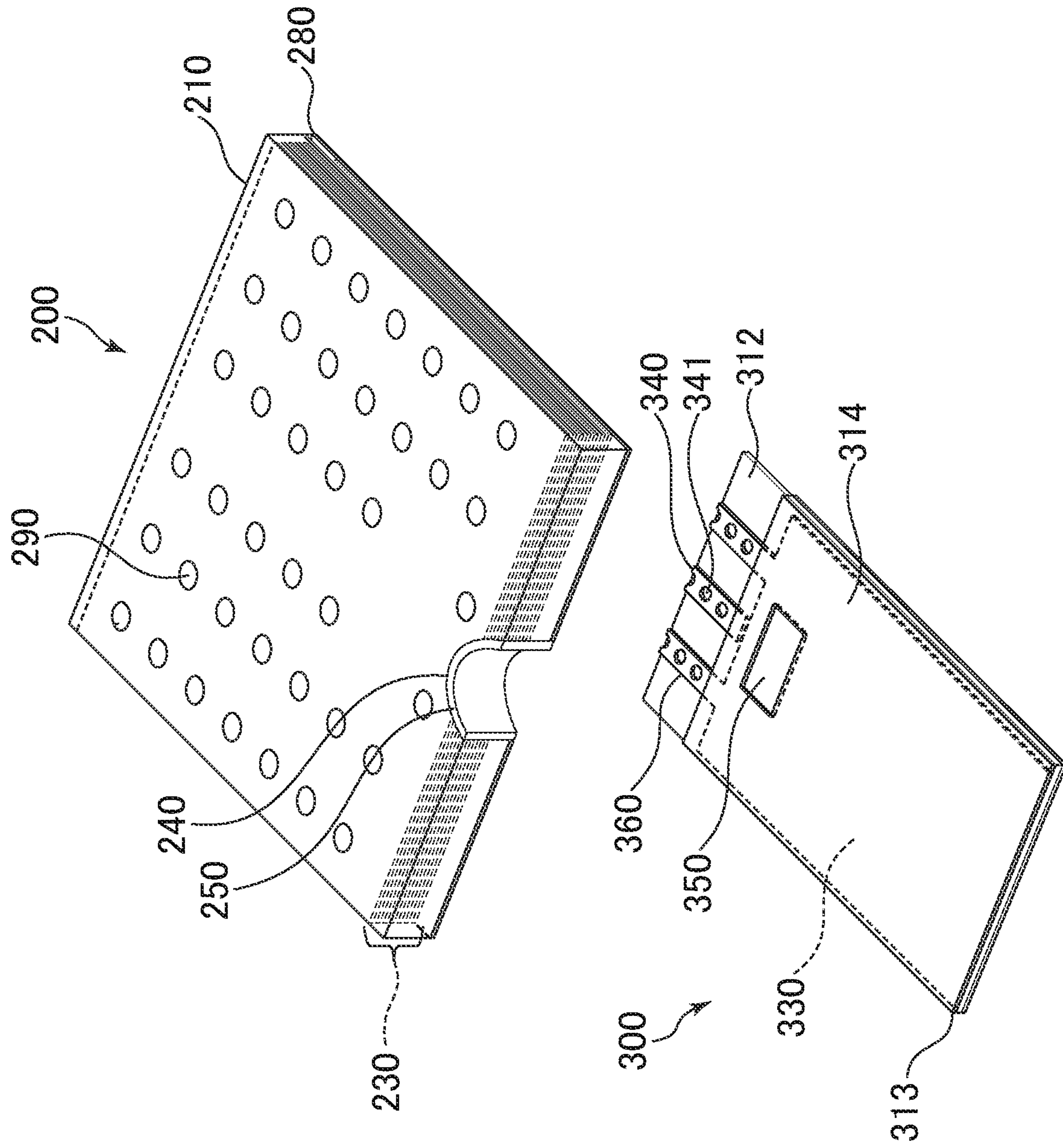


FIG.2
300
310
311
320
341
361
312
360
340
230
270
250
240
211
260
270
212
220
200
280
210

FIG.3



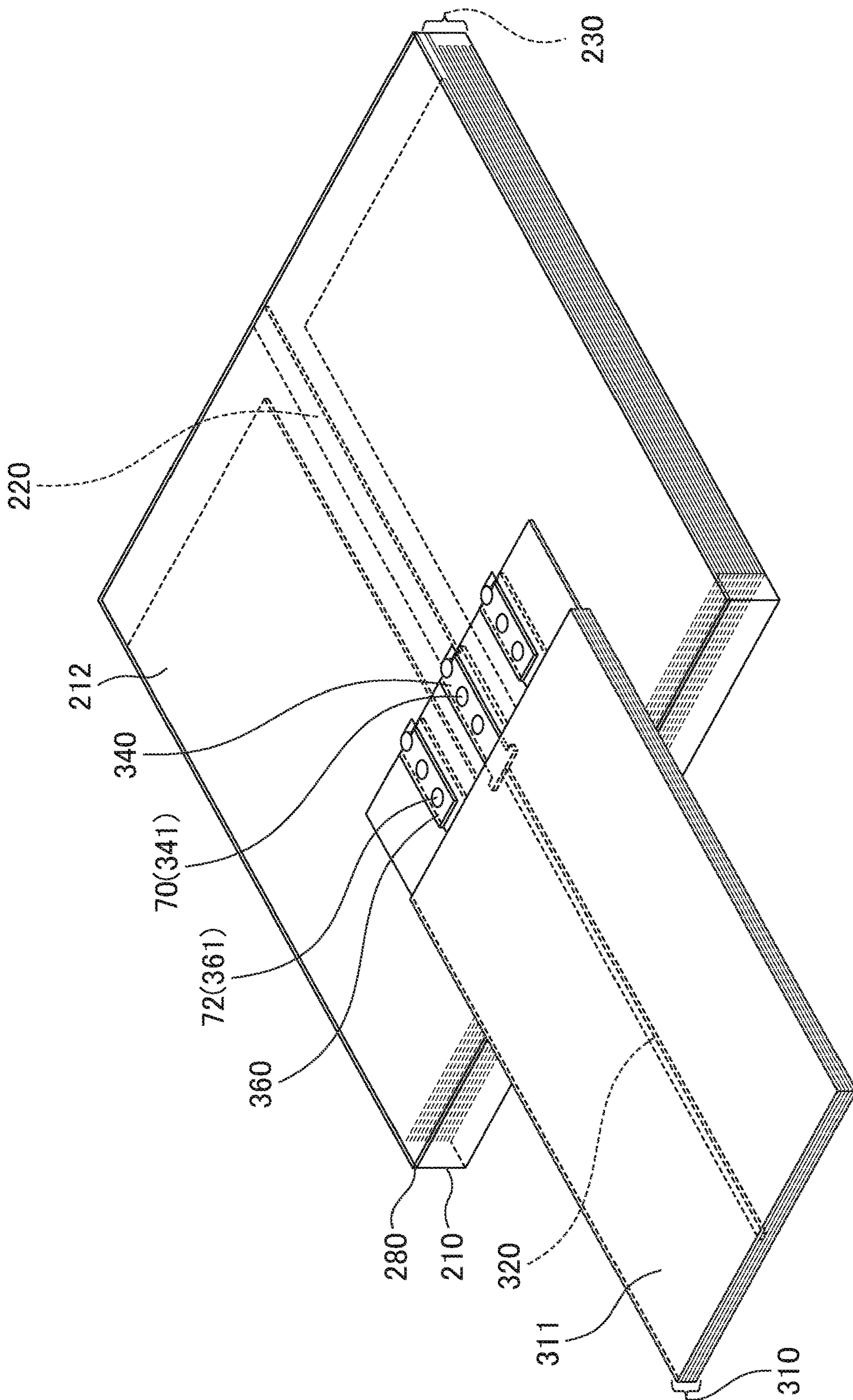


FIG.4
230
220
212
340
70(341)
72(361)
360
280
210
320
311
310

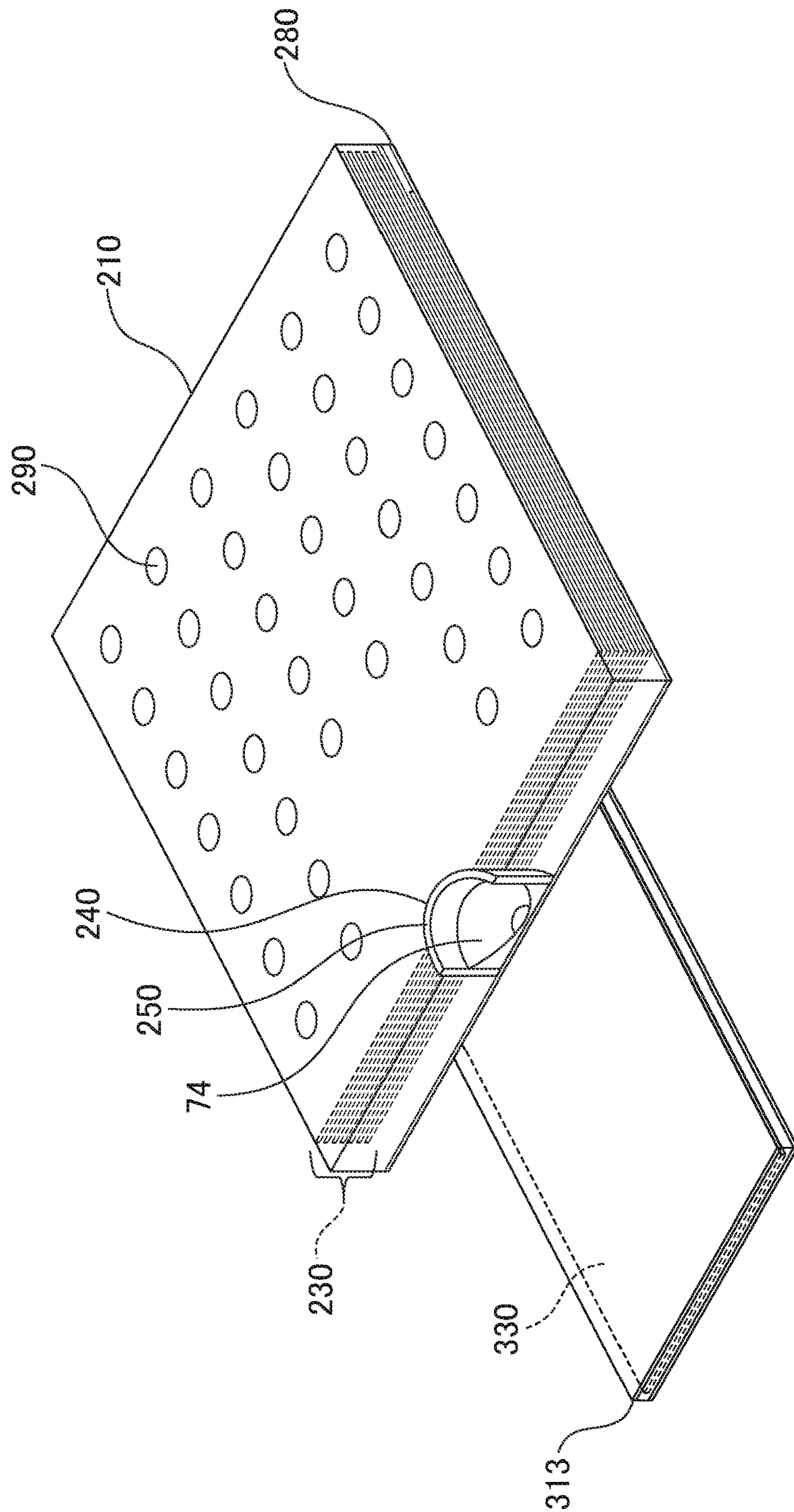
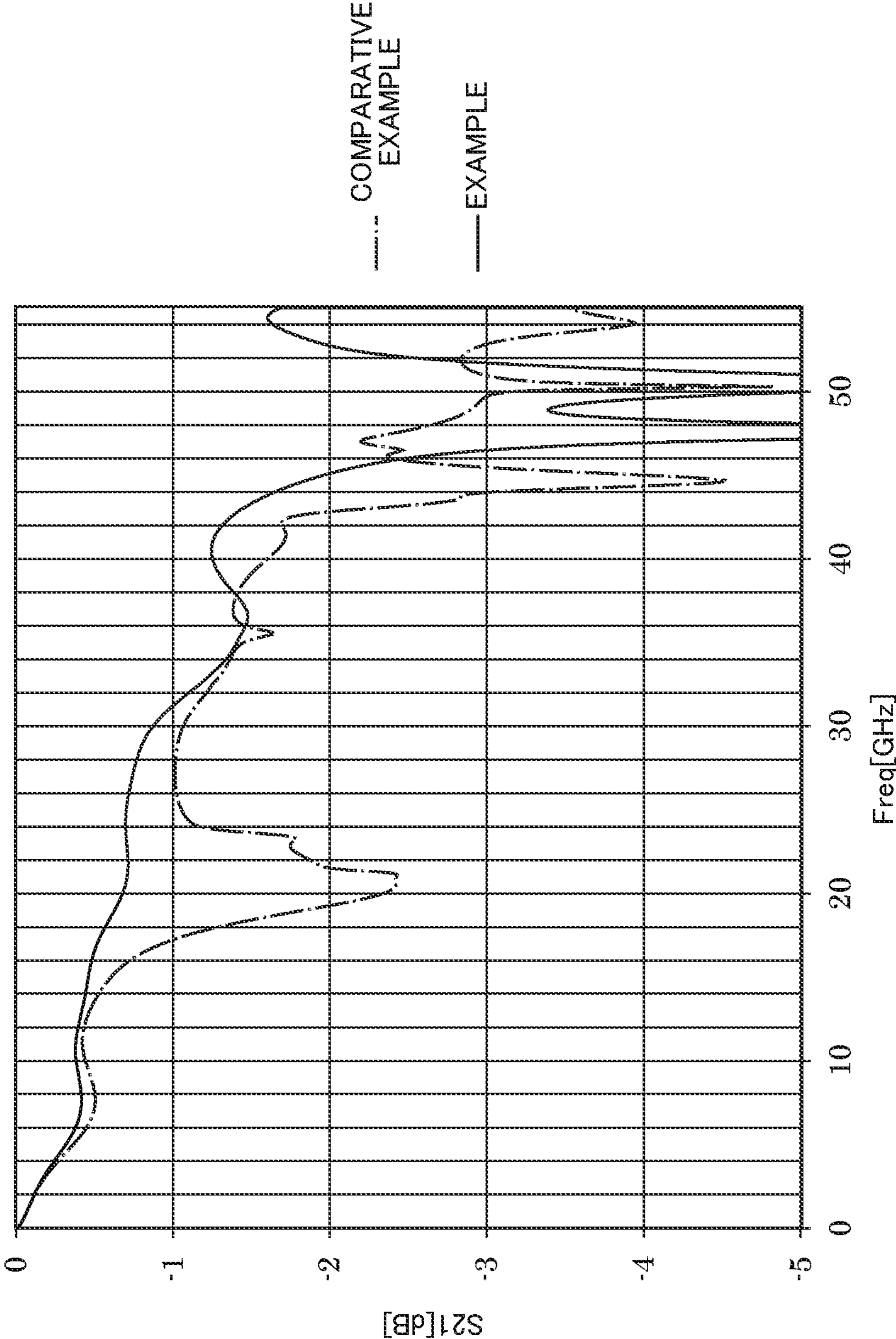


FIG.5
280
210
290
240
250
74
230
330
313

FIG.6



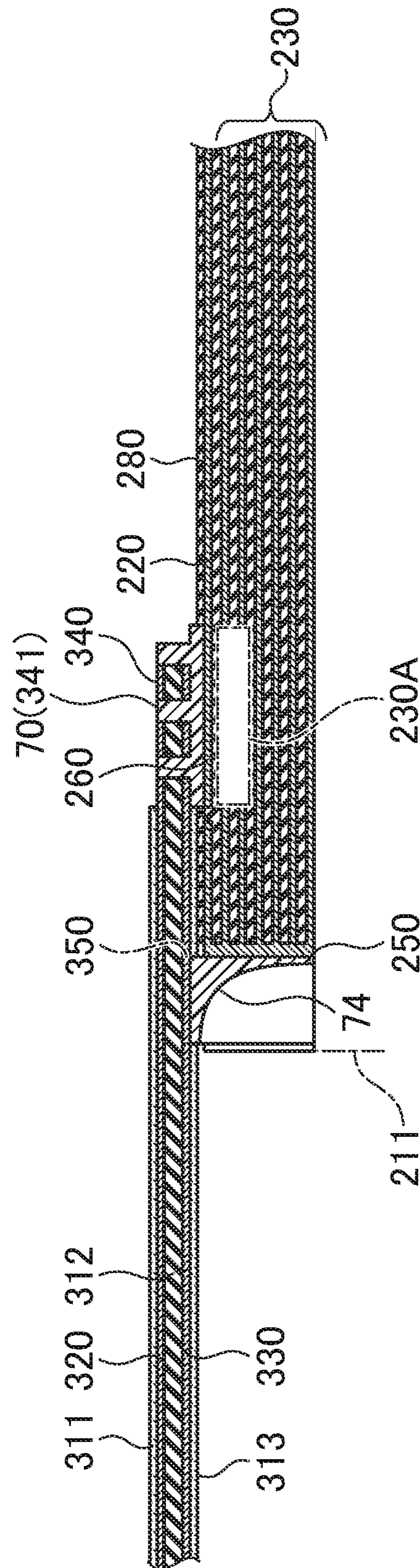


FIG.7
230
280
220
340
70(341)
230A
260
350
250
74
211
312
320
330
311
313

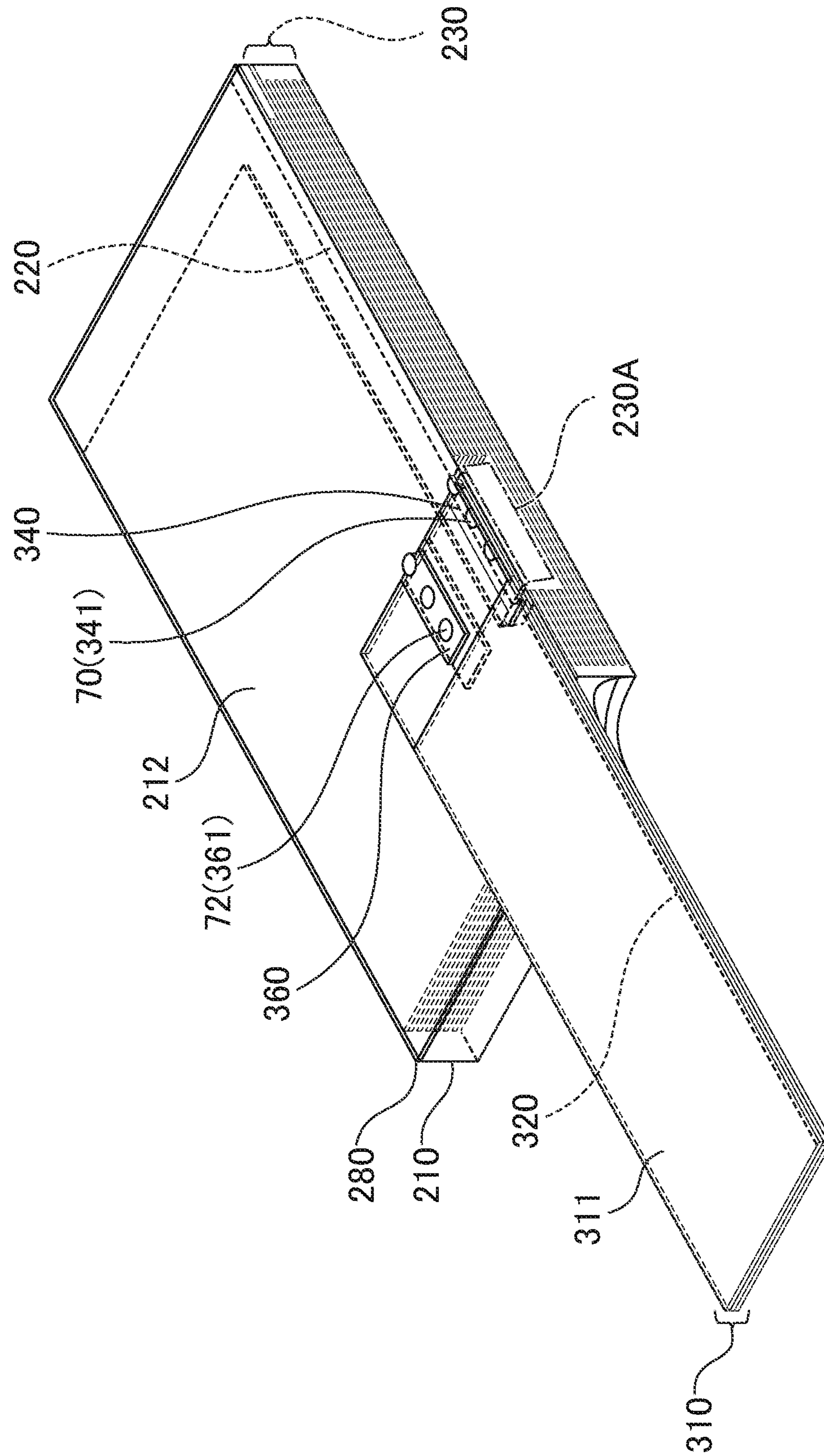


FIG.8
230
220
230A
340
70(341)
212
72(361)
360
280
210
320
311
310

FIG.9

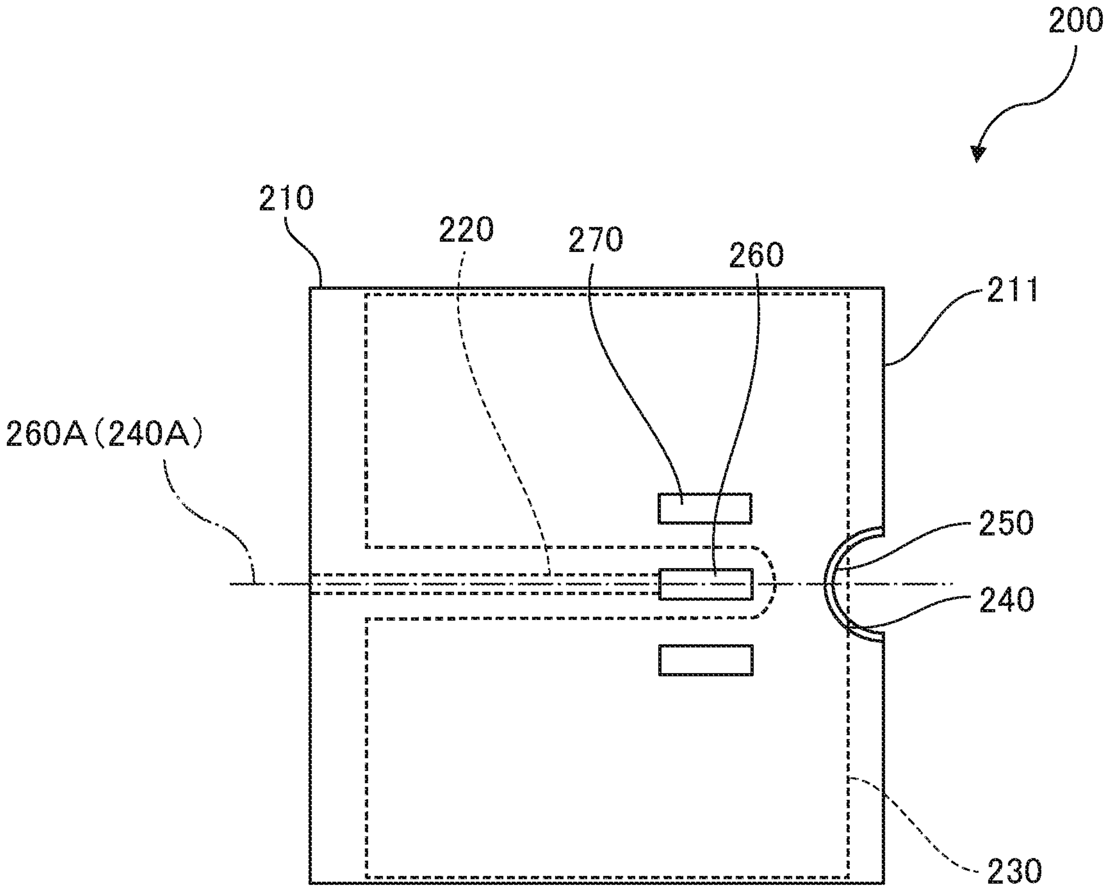


FIG.10

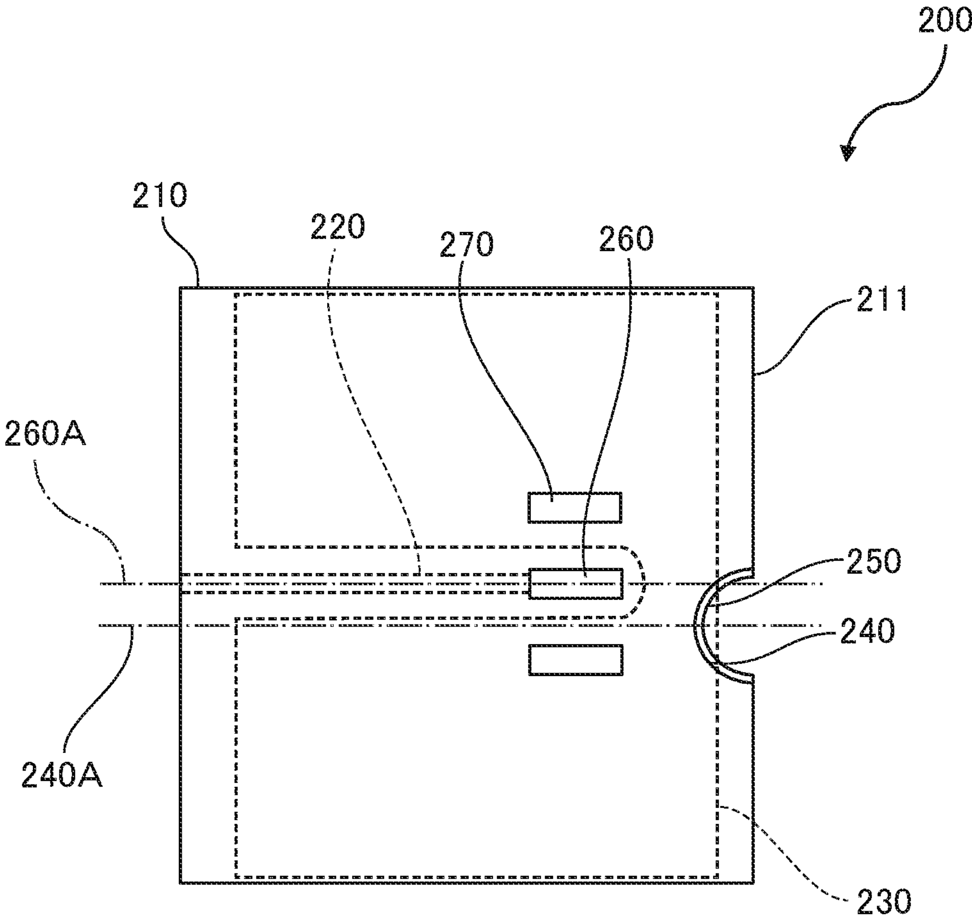


FIG.11

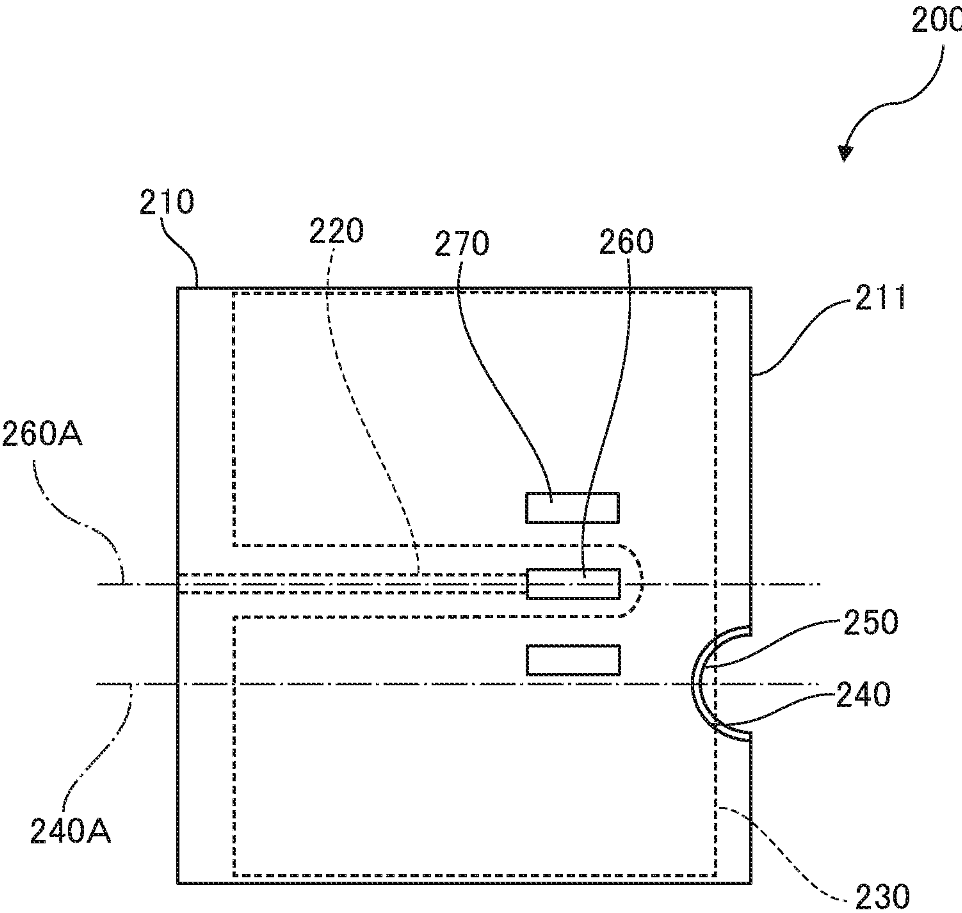


FIG.12

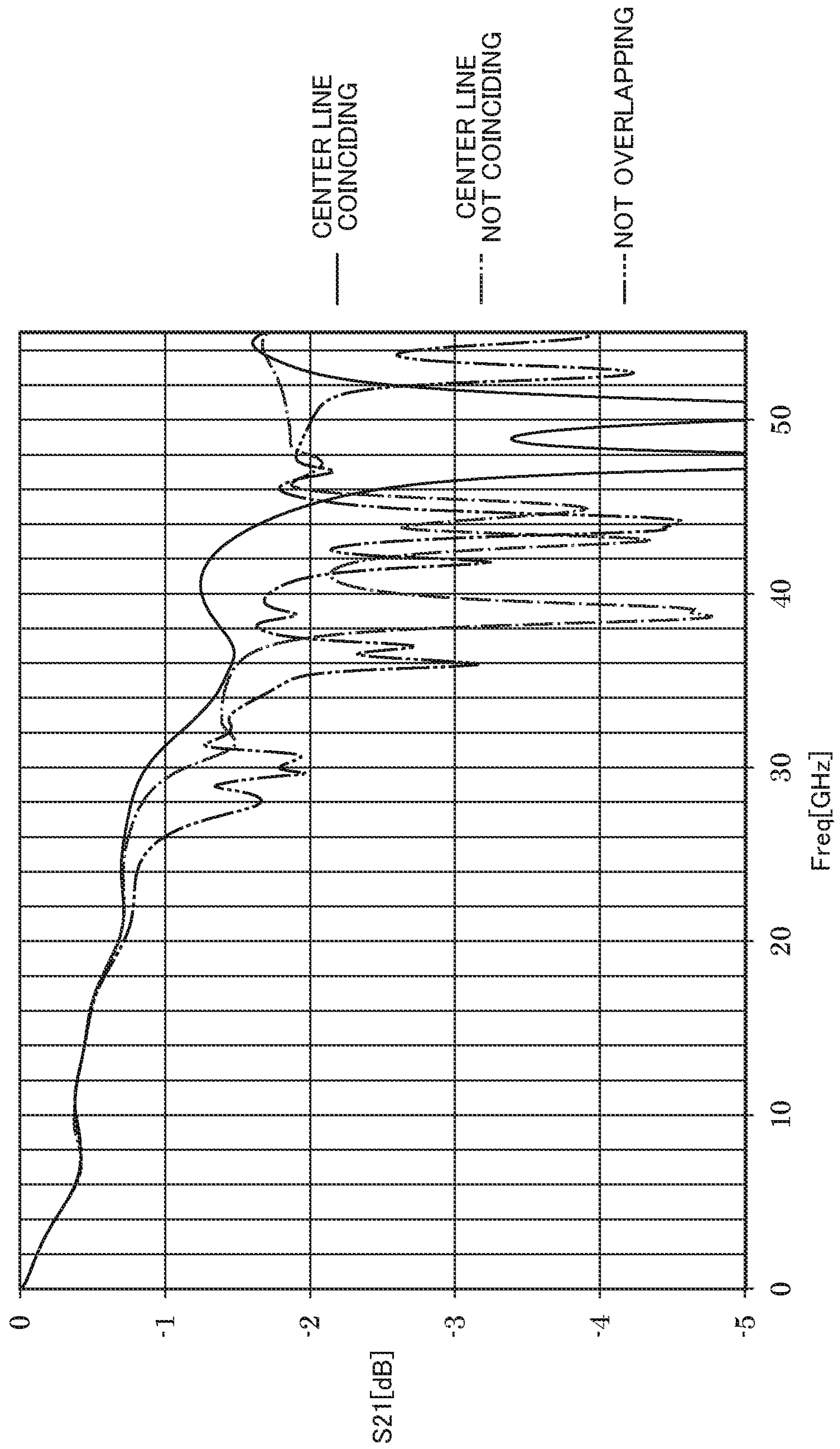
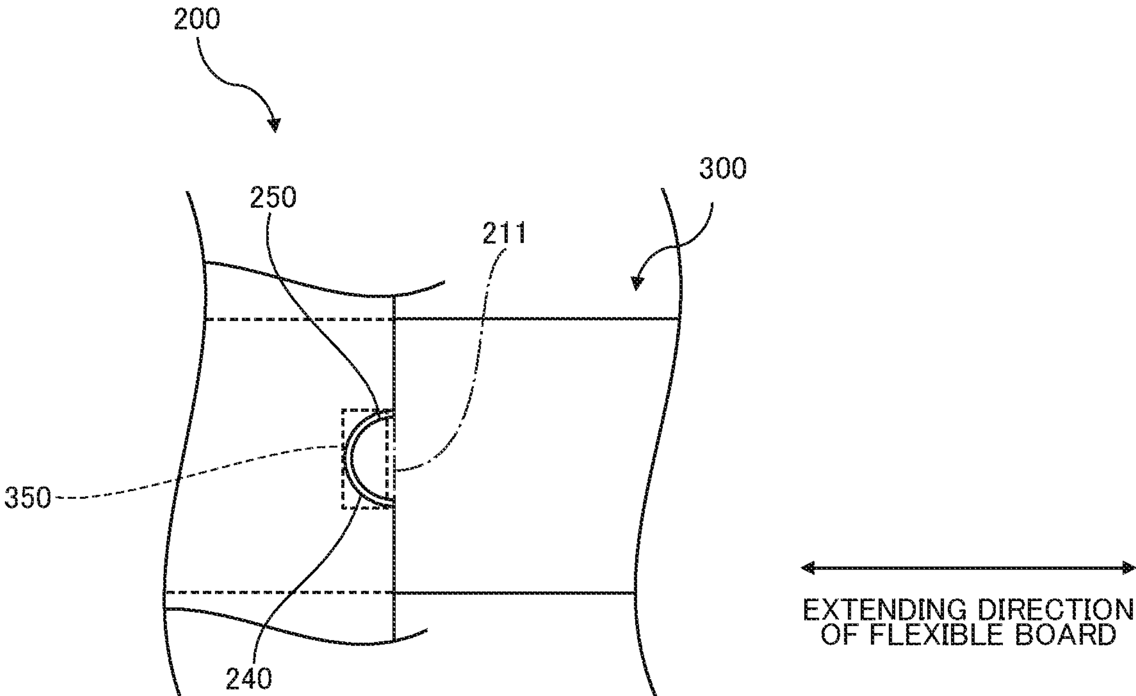


FIG.13



OPTICAL MODULE AND METHOD FOR MANUFACTURING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority from Japanese application JP 2019-001667 filed on Jan. 9, 2019, which is hereby expressly incorporated by reference herein.

TECHNICAL FIELD

The present disclosure relates to an optical module and a manufacturing method for an optical module.

BACKGROUND

Currently, most of the Internet and telephone networks are constructed by optical communication networks. Optical modules used as interfaces for routers/switches and transmission devices that are optical communication devices have an important role in converting electrical signals into optical signals. In general, an optical module includes an optical subassembly containing an optical element, a printed circuit board mounted with an IC for processing a signal including a modulated electric signal, and a flexible printed board electrically connected therebetween.

An optical subassembly may include a ground conductor on the end surface of a transmission line so that one component is orthogonal to the signal wiring of the transmission line, and the upper surface of the ground conductor and the lower surface of a ground conductor disposed on the lower surface of the other component are connected by solder. With such an optical subassembly, part of the high-frequency signal may be suppressed from being radiated into the air from the transmission line, and signal transmission characteristics in a high-frequency band are improved.

SUMMARY

According to some possible implementations, an optical module may include: a printed circuit board; and a flexible board. The printed circuit board may include an insulating base, a first transmission line provided on the insulating base, a first ground conductor disposed in the insulating base, a notch portion formed on a side surface of the insulating base such that the first ground conductor is partially exposed, a conductor provided in the notch portion and electrically connected to the first ground conductor, and a first electrode exposed on a main surface of the insulating base facing the flexible board and electrically connected to the first transmission line. The flexible board may include an insulating sheet including a plurality of insulating layers, a second transmission line provided on the insulating sheet, a second ground conductor disposed in the insulating sheet, a second electrode exposed on a main surface of the insulating sheet facing the printed circuit board and connected to the second transmission line, and a third electrode exposed on the main surface of the insulating sheet facing the printed circuit board and connected to the second ground conductor. The first electrode and the second electrode may be electrically connected, and the conductor and the third electrode may be connected by solder.

According to some possible implementations, a method for manufacturing an optical module may include: preparing an in-process printed circuit board including: an insulating base, a first transmission line provided on the insulating base, a first ground conductor disposed in the insulating base, and a first electrode exposed on a main surface of the insulating base facing the flexible board and electrically connected to the first transmission line; forming a notch portion on a side surface of the insulating base such that the first ground conductor is partially exposed from the side surface; forming a conductor electrically connected to the first ground conductor at the notch portion; preparing a flexible board including: an insulating sheet including a plurality of insulating layers, a second transmission line provided on the insulating sheet, a second ground conductor disposed in the insulating sheet, a second electrode exposed on a main surface of the insulating sheet facing the printed circuit board and connected to the second transmission line, and a third electrode exposed on the main surface of the insulating sheet facing the printed circuit board and connected to the second ground conductor; disposing the flexible board and the printed circuit board so that at least a part of the third electrode overlaps at least a part of a region surrounded by the conductor and the side surface when viewed from a direction orthogonal to the main surface of the insulating base; and applying solder from the conductor to the electrode.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an external view of an optical module.

FIG. **2** is a perspective view showing a state before a printed circuit board and a flexible board are connected.

FIG. **3** is a perspective view showing a state before the printed circuit board and the flexible board are connected.

FIG. **4** is a perspective view showing a state in which the printed circuit board and the flexible board are connected.

FIG. **5** is a perspective view showing a state in which the printed circuit board and the flexible board are connected.

FIG. **6** is a graph obtained by calculating transmission characteristics from the printed circuit board to the flexible board by using a high frequency structure simulator (HFSS) as a three-dimensional electromagnetic field simulator, according to an example and a comparative example.

FIG. **7** is a schematic view showing a cross-sectional structure of a first transmission line and a center line of a second transmission line.

FIG. **8** is a schematic perspective view showing a cross-sectional structure of the first transmission line and the center line of the second transmission line.

FIG. **9** is a schematic plan view of the printed circuit board.

FIG. **10** is a schematic plan view of a printed circuit board according to another example.

FIG. **11** is a schematic plan view of a printed circuit board according to another example.

FIG. **12** is a graph obtained by calculating transmission characteristics from the printed circuit board to the flexible board by using a high frequency structure simulator (HFSS) as the three-dimensional electromagnetic field simulator.

FIG. **13** is a schematic plan view in which an overlapping portion of a notch portion and a third electrode is enlarged.

DETAILED DESCRIPTION

The following detailed description of example implementations refers to the accompanying drawings. The same reference numbers in different drawings may identify the same or similar elements.

FIG. **1** is an external view of an optical module **1** for optical communication in the present implementation. A

modulated electric signal is transmitted to an optical subassembly **100** via a flexible board **300** connected to a printed circuit board **200** by solder or the like from a driving IC (not shown) mounted on the printed circuit board **200**. The optical subassembly **100** contains an optical element and includes an interface that transmits and receives outgoing light or incident light. The optical subassembly **100** includes an eyelet **120** and an optical receptacle **2**. Although not shown, the optical subassembly **100**, the printed circuit board **200**, and the flexible board **300** are built in a housing made of metal or the like to constitute the optical module **1**.

Examples of the optical subassembly **100** include a transmitter optical subassembly (TOSA) that has a light-emitting element such as a laser diode therein, converts an electrical signal into an optical signal, and transmits the optical signal, a receiver optical subassembly (ROSA) that has a light-receiving element such as a photodiode therein and converts the received optical signal into an electrical signal, a bidirectional optical subassembly (BOSA) that has both of these functions, and the like. The present implementation can be applied to any of the above optical subassemblies, and in the present implementation, a transmitter optical subassembly will be described as an example.

FIG. **2** is a perspective view showing a state before the printed circuit board **200** and the flexible board **300** according to the present implementation are connected, when viewed from above. FIG. **3** is a perspective view showing a state before the printed circuit board **200** and the flexible board **300** according to the present implementation are connected, when viewed from below.

As shown in FIGS. **2** and **3**, the printed circuit board **200** includes an insulating base **210**, a first transmission line **220**, a first ground conductor **230**, a notch portion **240**, a conductor **250**, and a first electrode **260**.

The first transmission line **220** that transmits an electrical signal to an optical element provided in the optical subassembly **100** is provided on the insulating base **210**. In FIGS. **2** and **3**, the first ground conductor **230** includes a plurality of ground conductors and is disposed in the insulating base **210**. The notch portion **240** is formed on a side surface **211** of the insulating base **210** such that the first ground conductor **230** is partially exposed. The notch portion **240** is formed with the conductor **250** electrically connected to the first ground conductor. The notch portion **240** and the conductor **250** constitute a castellation. The first electrode **260** is exposed on a main surface **212** (upper surface in FIG. **2**) of the insulating base **210** facing the flexible board **300**. The first electrode **260** is electrically connected to the first transmission line **220**. In FIG. **2**, a resist **280** is applied to the upper surfaces of the insulating base **210** and the first transmission line **220**. The resist **280** has a plurality of openings, and a part of the first transmission line **220** exposed from one of the openings is used as the first electrode **260**.

As shown in FIGS. **2** and **3**, the flexible board **300** includes an insulating sheet **310**, a second transmission line **320**, a second ground conductor **330**, a second electrode **340**, and a third electrode **350**.

The insulating sheet **310** includes a plurality of insulating layers. The insulating sheet **310** is provided with the second transmission line **320** that transmits an electrical signal to an optical element provided in the optical subassembly **100**. In FIG. **2**, the second transmission line **320** is provided between the insulating layer **311** and the insulating layer **312**. The second ground conductor **330** is disposed in the insulating sheet **310**, and is provided between the insulating layer **312** and the insulating layer **313** in FIG. **3**. The second electrode **340** is exposed on at least a main surface **314** of the insulating sheet **310** facing the printed circuit board **200**. The second electrode **340** is connected to the second transmission line **320** as shown in FIG. **2**. In FIGS. **2** and **3**, the second electrode **340** has a configuration in which two electrodes sandwich an insulating layer **312** and the two electrodes are electrically connected by solder filling a via **341**. The third electrode **350** is exposed on the main surface **314** of the insulating sheet **310**. The third electrode **350** is connected to the second ground conductor **330**. In FIG. **3**, the insulating layer **313** that is the outermost layer included in the insulating sheet **310** has an opening, and a part of the second ground conductor **330** exposed from the opening is used as the third electrode **350**.

FIG. **4** is a perspective view showing a state in which the printed circuit board **200** and the flexible board **300** according to the present implementation are connected, when viewed from above. FIG. **5** is a perspective view showing a state in which the printed circuit board **200** and the flexible board **300** according to the present implementation are connected, when viewed from below.

As shown in FIG. **4**, the first electrode **260** (see FIG. **2**) electrically connected to the first transmission line **220** provided on the printed circuit board **200** and the second electrode **340** (see FIG. **3**) connected to the second transmission line **320** provided on the flexible board **300** are electrically connected by solder **70** filling the via **341** provided in the second electrode **340**. As shown in FIG. **5**, the conductor **250** formed in the notch portion **240** provided in the printed circuit board **200** and electrically connected to the first ground conductor **230** and the third electrode **350** (see FIG. **3**) connected to the second ground conductor **330** provided on the flexible board **300** are connected by solder **74** applied from the conductor **250** to the third electrode **350**.

The above-mentioned configuration of the printed circuit board **200** and the flexible board **300** can improve the reliability of ground connection between the printed circuit board **200** and the flexible board **300**. That is, in the configuration of the present implementation, when the conductor **250** connected to the first ground conductor **230** in the printed circuit board **200** and the third electrode **350** connected to the second ground conductor **330** of the flexible board **300** are electrically connected by the solder **74**, the connection portion can be visually recognized from the outside. Therefore, the reliability of ground connection between the printed circuit board **200** and the flexible board **300** can be improved.

Further, in FIG. **2**, the printed circuit board **200** includes two fourth electrodes **270** connected to the first ground conductor **230**. In FIG. **2**, the resist **280** has a plurality of openings, and a part of the first ground conductor **230** exposed from two of the openings is used as the fourth electrode **270**. That is, the resist **280** formed on the upper surface of the insulating base **210** of the printed circuit board **200** is not applied to the first electrode **260** and the fourth electrode **270**, and the first electrode **260** and the fourth electrode **270** are exposed from the resist **280**. Due to the presence of the resist **280**, the solder applied to the first electrode **260** and the fourth electrode **270** can be prevented from flowing in the direction of the main surface **212** of the insulating base **210**.

In FIGS. **2** and **3**, the flexible board **300** includes two fifth electrodes **360** connected to the second ground conductor **330**. The fifth electrode **360** has a configuration in which two electrodes sandwich the insulating layer **312** and the two electrodes are electrically connected by solder filling a via **361**.

As shown in FIG. **2**, the fourth electrode **270** provided on the printed circuit board **200** and the fifth electrode **360** provided on the flexible board **300** are electrically connected by solder **72** filling the via **361** provided in the fifth electrode **360** as shown in FIG. **4**. Such a configuration can further strengthen the ground connection between the printed circuit board **200** and the flexible board **300**.

An optical module is enhanced in speed and reduced in size and cost with the spread of broadband networks in recent years. In order to reduce the size of the optical module **1**, not only the optical subassembly **100** included in the optical module **1** but also the IC and the printed circuit board **200** are required to be reduced. In order to reduce the size of the IC, recent IC packages are offered as ball grid array (BGA) types, and the ball-shaped terminals at that time are arranged at a pitch of approximately 0.5 mm. Furthermore, high-density mounting is realized by adopting a full grid configuration in which all of grids on a terminal mounting surface are filled with terminals.

However, since it is difficult to pass the wiring between terminals of 0.5 mm, among the terminals disposed in a grid pattern, it is necessary to connect the printed circuit board **200** to the terminals disposed inside the second and subsequent rows of the grid by using wiring extending between a plurality of insulating layers constituting the insulating base **210** of the printed circuit board **200**.

Here, since the land diameter increases and interference occurs between adjacent terminals in the case of forming a via in the IC with a drill, it is difficult to wire the inner terminals of the second and subsequent rows in the full grid. Therefore, it is desirable to form a via by using a laser in order to reduce the land diameter. All the terminals of the full grid provided in the IC can be connected to the wiring extending between the plurality of insulating layers in the printed circuit board **200**. Therefore, the material of the insulating base **210** constituting the printed circuit board **200** receives restrictions such as laser output and cost, and thus the base thickness, the dielectric constant, the dielectric loss tangent, and the like are naturally determined. The printed circuit board **200** includes the first ground conductor **230** composed of a plurality of ground conductors in order to enable high-density mounting. As shown in FIG. **5**, the plurality of ground conductors included in the first ground conductor **230** are electrically connected to each other by a plurality of vias **290** that penetrate the printed circuit board **200**.

In recent years, a demand for optical modules capable of transmitting high-speed electrical signals of 50 Gbit/s has been increasing due to high speed requirements. Under such high-speed transmission, in the case of connecting the printed circuit board **200** including the first ground conductor **230** composed of a plurality of ground conductors to the optical subassembly **100** by using the solder or the like via the flexible board **300**, the ground resonance at the connection point between the printed circuit board **200** and the flexible board **300** becomes large, and the waveform quality of the optical module **1** may be deteriorated. That is, at the connection portion between the printed circuit board **200** and the flexible board **300**, the signal wiring of the flexible board **300** may serve as an excitation source and induce parallel plate resonance.

However, as shown in FIGS. **4** and **5**, in the optical module **1** according to the present implementation, the first ground conductor **230** of the printed circuit board **200** and the second ground conductor **330** of the flexible board **300** are connected by the shortest path by using the solder **74**, and therefore the delay of the return current can be suppressed and the occurrence of the parallel plate resonance phenomenon can be suppressed.

FIG. **6** is a graph obtained by calculating the transmission characteristics from the printed circuit board **200** to the flexible board **300** by using a high frequency structure simulator (HFSS) as a three-dimensional electromagnetic field simulator, according to an example and a comparative example of the present implementation. The graph of the example shown in FIG. **6** shows the transmission characteristics in a state where the printed circuit board **200** includes the notch portion **240** and the conductor **250**, and the conductor **250** and the third electrode **350** (see FIG. **3**) of the flexible board **300** are connected by the solder **74** as shown in FIGS. **4** and **5**. The graph of the comparative example shown in FIG. **6** shows the transmission characteristics in a state where the printed circuit board **200** does not include the conductor **250**. That is, the connection between the ground conductors of the printed circuit board **200** and the flexible board **300** in the comparative example is only the connection between the fourth electrode **270** of the printed circuit board **200** and the fifth electrode **360** of the flexible board **300**.

As shown in FIG. **6**, compared with the graph of the comparative example, in the graph of the example, since the first ground conductor **230** of the printed circuit board **200** and the second ground conductor **330** of the flexible board **300** are connected by the shortest path by using the solder **74**, it is understood that the deterioration of the transmission characteristics due to the parallel plate resonance phenomenon is suppressed.

As long as the occurrence of this parallel plate resonance phenomenon is to be suppressed, a through-hole penetrating the printed circuit board **200** may be provided, and the first ground conductor **230** and the second ground conductor **330** may be connected via the through-hole. In contrast, in the present implementation, as described above, the notch portion **240** is provided in the side surface **211** of the printed circuit board **200**, and the conductor **250** connected to the first ground conductor is formed in the notch portion **240**. With such a configuration, when the conductor **250** connected to the first ground conductor **230** and the third electrode **350** connected to the second ground conductor **330** are electrically connected by the solder **74**, the connection portion can be visually recognized from the outside. As a result, the reliability of ground connection between the printed circuit board **200** and the flexible board **300** can be improved. As shown in FIG. **1**, the flexible board **300** is often stored in the optical module **1** in a bent state. Therefore, the flexible board **300** may be peeled off from the printed circuit board **200**, for example, upward in FIG. **1**. Since the solder **72** remains only in the exposed region of each electrode at the connection point between the fourth electrode **270** of the printed circuit board **200** and the fifth electrode **360** of the flexible board **300**, a sufficient amount of solder may not be supplied and sufficient connection strength may not be obtained. However, since the solder **74** can be supplied to a region wide to some extent by connecting the conductor **250** connected to the first ground conductor **230** and the third electrode **350** connected to the second ground conductor **330** by the solder **74** provided in the notch portion **240**, sufficient connection strength can be obtained, and an effect of suppressing the flexible board **300** from being peeled off from the printed circuit board **200** can be obtained. That is, not only the connection reliability at the time of manufacturing but also the connection reliability from a long-term viewpoint can be ensured. Furthermore, rather than simply connecting to the ground at the side of the

printed circuit board **200**, the notch **240** is provided and the ground connection is made thereat, whereby the effect that the solder **74** remains in the vicinity of the connection point can be obtained. In a case where the notch portion **240** is not provided, that is, in a case where the conductor is provided on the entire side of the printed circuit board **200**, since the solder spreads over the entire side, the solder may not remain at the connection point between the printed circuit board **200** and the flexible board **300**, the solder may be insufficient at the connection portion, and the necessary connection strength may not be obtained. This problem may be solved by providing the notch portion **240**. It is possible to secure a component mounting region on the printed circuit board **200** by providing the notch portion **240** and the conductor **250** rather than forming a through-hole penetrating the printed circuit board **200**. Therefore, according to the configuration of the present implementation, it is possible to strengthen the ground connection between the printed circuit board **200** and the flexible board **300** while expanding the component mounting region in the printed circuit board **200**, and it is also possible to improve the visibility of the ground connection portion of the printed circuit board **200** and the flexible board **300**.

FIG. **7** is a schematic view showing a cross-sectional structure of the first transmission line **220** and the center line of the second transmission line **320**. As shown in FIG. **7**, since the conductor **250** provided on the side surface **211** of the printed circuit board **200**, and the third electrode **350** of the flexible board **300** are orthogonal to each other, fillets are easily formed, and the strength of the connection portion between the printed circuit board **200** and the flexible board **300** can be improved.

FIG. **8** is a schematic perspective view showing a cross-sectional structure of the first transmission line **220** and the center line of the second transmission line **320**. As shown in FIGS. **7** and **8**, the optical module **1** according to the present implementation is configured such that the first ground conductor **230** has an opening **230**A at a position overlapping the first electrode **260** when viewed from the direction orthogonal to the main surface **212** of the insulating base **210**. Such a configuration can further improve the accuracy of impedance matching. For example, even in a case where displacement occurs between the first electrode **260** of the printed circuit board **200** and the second electrode **340** of the flexible board **300** in the manufacturing process, in order to reduce the change in the contact area between the first electrode **260** and the second electrode **340**, the width (length in the direction perpendicular to the extending direction of the first transmission line **220**) of the first electrode **260** is made larger than the width of the first transmission line **220** as shown in FIG. **2**. For this reason, the impedance decreases as the area of the first electrode **260** increases. With respect to this problem, as shown in FIGS. **7** and **8**, the first ground conductor **230** has the opening **230**A at a position overlapping the first electrode **260** when viewed from the direction orthogonal to the main surface **212** of the insulating base **210**, thereby making it possible to adjust impedance and perform impedance matching.

FIGS. **9**, **10**, and **11** are schematic plan views of the printed circuit board **200** according to the present implementation. FIG. **12** is a graph obtained by calculating the transmission characteristics from the printed circuit board **200** to the flexible board **300** for the configurations according to FIGS. **9**, **10**, and **11** by using a high frequency structure simulator (HFSS) as a three-dimensional electromagnetic field simulator.

In the configuration shown in FIG. **9**, a center line **260**A of the first electrode **260** overlaps the notch portion **240** when viewed from the direction orthogonal to the main surface **212** of the insulating base **210**. In the configuration shown in FIG. **9**, a center line **240**A of the notch portion **240** and the center line **260**A of the first electrode **260** coincide with each other when viewed from the direction orthogonal to the main surface **212** of the insulating base **210**. Here, the center line **260**A of the first electrode **260** means a straight line parallel to the extending direction of the first transmission line **220** and passing through the center position of the first electrode **260** in the direction orthogonal to the extending direction. The center line **240**A of the notch portion **240** means a straight line parallel to the extending direction of the first transmission line **220** and passing through the center position of the notch portion **240** in the direction orthogonal to the extending direction.

In the configuration shown in FIG. **10**, the center line **260**A of the first electrode **260** overlaps the notch portion **240** when viewed from the direction orthogonal to the main surface **212** of the insulating base **210**. In the configuration shown in FIG. **10**, the center line **240**A of the notch portion **240** and the center line **260**A of the first electrode **260** do not coincide with each other when viewed from the direction orthogonal to the main surface **212** of the insulating base **210**.

In the configuration shown in FIG. **11**, the center line **260**A of the first electrode **260** does not overlap the notch portion **240** when viewed from the direction orthogonal to the main surface **212** of the insulating base **210**. In the configuration shown in FIG. **11**, the center line **240**A of the notch portion **240** and the center line **260**A of the first electrode **260** do not coincide with each other when viewed from the direction orthogonal to the main surface **212** of the insulating base **210**.

In FIG. **12**, the transmission characteristics for the configuration shown in FIG. **9** are displayed as "center line coinciding". The transmission characteristics for the configuration shown in FIG. **10** are displayed as "center line not coinciding". The transmission characteristics for the configuration shown in FIG. **11** are displayed as "not overlapping".

As shown in FIG. **12**, it is understood that in the transmission characteristics according to the configurations shown in FIGS. **9** and **10**, dip is less and stable transmission can be performed, compared with the transmission characteristics according to the configuration shown in FIG. **11**. In particular, in order to perform transmission of 50 Gbit/s, it is necessary to perform stable transmission up to 35 GHz. The configurations shown in FIGS. **9** and **10** are desirable because the transmission characteristics do not have a large dip even in the vicinity of 35 GHz. Accordingly, as shown in FIGS. **9** and **10**, it is desirable that the center line **260**A of the first electrode **260** overlaps the notch portion **240** when viewed from the direction orthogonal to the main surface **212** of the insulating base **210**.

As shown in FIG. **12**, comparing the transmission characteristics according to the configuration shown in FIG. **9** and the transmission characteristics according to the configuration shown in FIG. **10**, it is understood that in the configuration shown in FIG. **9** in which the center line **240**A of the notch portion **240** coincides with the center line **260**A of the first electrode **260** when viewed from the direction orthogonal to the main surface **212** of the insulating base **210**, there is no large dip even in the transmission over 40 GHz and stable transmission can be performed. Therefore, from the viewpoint of stable signal transmission, it is

desirable that the center line **240**A of the notch portion **240** and the center line **260**A of the first electrode **260** coincide with each other as shown in FIG. **9**.

On the other hand, with the configuration shown in FIG. **10**, since the allowable range for the position where the notch portion **240** is disposed increases, the degree of freedom of component mounting on the printed circuit board **200** increases. Therefore, it can be said that the configuration shown in FIG. **10** is more desirable than the configuration shown in FIG. **9** from the viewpoint of the degree of design freedom regarding component mounting on the printed circuit board **200**. That is, the configuration shown in FIG. **10** can be said to be a configuration that realizes both the stability of transmission and the degree of freedom of component mounting.

FIG. **13** is a schematic plan view in which the overlapping portion of the notch portion **240** and the third electrode **350** according to the present implementation is enlarged. As shown in FIG. **13**, in the extending direction of the insulating sheet **310**, the entire third electrode **350** is disposed at the same position on the printed circuit board **200** as the side surface **211** where the notch portion **240** is formed or on an inner side of the printed circuit board **200** further than the side surface **211**. In FIG. **13**, the entire third electrode **350** is disposed on the inner side of the printed circuit board **200** further than the side surface **211** in the extending direction of the insulating sheet **310**. By adopting such a configuration, the following advantages can be obtained.

First, the flexible board **300** has a role of absorbing variations in the overall length of the optical module **1**. The flexible board **300** has a role of absorbing stress generated on the printed circuit board **200** side and suppressing transmission of the stress to the optical subassembly **100**. In the present implementation, as shown in FIGS. **5** and **7**, by adopting a configuration in which the entire third electrode **350** is disposed at the same position as the side surface **211** or on the inner side of the printed circuit board **200** further than the side surface **211** in the extending direction of the insulating sheet **310**, due to the presence of the solder **74**, the influence of the loss of flexibility in the extending direction of the insulating sheet **310** on the flexible board **300** can be reduced and the loss of the two roles described above can be suppressed.

The optical module **1** according to the present implementation as described above can be manufactured through the following manufacturing process.

An in-process printed circuit board including the insulating base **210**, the first transmission line **220** provided on the insulating base **210**, the first ground conductor **230** disposed in the insulating base **210**, and the first electrode **260** exposed on the main surface **212** of the insulating base **210** facing the flexible board **300** and electrically connected to the first transmission line **220** is prepared.

Next, as shown in FIGS. **2** and **3**, the notch portion **240** that exposes a part of the first ground conductor **230** from the side surface **211** of the insulating base **210** is formed.

Thereafter, the conductor **250** that is electrically connected to the first ground conductor **230** is formed at the notch portion **240**. In a case where the first ground conductor **230** includes a plurality of ground conductors, the plurality of ground conductors are electrically connected to each other by forming the conductor **250**.

A process for preparing the flexible board **300** is performed in parallel with or before and after the three processes of a process of preparing the in-process printed circuit board described above, a process of forming the notch portion **240**, and a process of forming conductor **250**. That is, the order of the above three processes and the process of preparing the flexible board **300** is not limited. In the process of preparing the flexible board **300**, as shown in FIGS. **2** and **3**, the flexible board **300** including the insulating sheet **310** including a plurality of insulating layers **311**, **312**, and **313**, the second transmission line **320** provided on the insulating sheet **310**, the second ground conductor **330** disposed in the insulating sheet **310**, the second electrode **340** exposed on the main surface **314** of the insulating sheet **310** facing the printed circuit board **200** and connected to the second transmission line **320**, and the third electrode **350** exposed on the main surface **314** of the insulating sheet **310** and connected to the second ground conductor **330** is prepared.

Thereafter, as shown in FIG. **5**, the upper surface of the printed circuit board **200** is mounted on the back-surface side of the flexible board **300**. At that time, when viewed from the direction orthogonal to the main surface **212** of the printed circuit board **200**, the flexible board **300** and the printed circuit board **200** are disposed so that at least a part of the third electrode **350** electrically connected to the second ground conductor **330** in the flexible board **300** overlaps at least a part of a region surrounded by the conductor **250** and the side surface **211**.

As shown in FIG. **5**, the solder **74** is applied from the conductor **250** of the printed circuit board **200** to the third electrode **350** of the flexible board **300**, and the conductor **250** and the third electrode **350** are electrically connected.

By such a manufacturing process, the optical module **1** according to the present implementation described above can be manufactured.

It is possible to suppress a change in impedance caused by ground connection between the printed circuit board **200** and the flexible board **300** by using such a manufacturing method. That is, when the printed circuit board **200** and the flexible board **300** are connected to the ground, for example, in a case where heat is applied from the insulating layer **311** (see FIG. **4**) side of the flexible board **300** in order to melt the solder disposed between the two, a part of the insulating layer **311** may be peeled off due to the heat. When a part of the insulating layer **311** is peeled off, voids may be generated in the insulating layer **311**, the dielectric constant in the insulating layer **311** may change, and the impedance may change. However, with the above manufacturing method, the conductor **250** and the third electrode **350** can be electrically connected by the solder **74** without applying such heat from the insulating layer **311** side. As a result, a change in impedance caused by ground connection between the printed circuit board **200** and the flexible board **300** can be suppressed.

The foregoing disclosure provides illustration and description, but is not intended to be exhaustive or to limit the implementations to the precise forms disclosed. Modifications and variations may be made in light of the above disclosure or may be acquired from practice of the implementations.

Even though particular combinations of features are recited in the claims and/or disclosed in the specification, these combinations are not intended to limit the disclosure of various implementations. In fact, many of these features may be combined in ways not specifically recited in the claims and/or disclosed in the specification. Although each dependent claim listed below may directly depend on only one claim, the disclosure of various implementations includes each dependent claim in combination with every other claim in the claim set.

No element, act, or instruction used herein should be construed as critical or essential unless explicitly described

as such. Also, as used herein, the articles "a" and "an" are intended to include one or more items, and may be used interchangeably with "one or more." Further, as used herein, the article "the" is intended to include one or more items referenced in connection with the article "the" and may be used interchangeably with "the one or more." Furthermore, as used herein, the term "set" is intended to include one or more items (e.g., related items, unrelated items, a combination of related and unrelated items, etc.), and may be used interchangeably with "one or more." Where only one item is intended, the phrase "only one" or similar language is used. Also, as used herein, the terms "has," "have," "having," or the like are intended to be open-ended terms. Further, the phrase "based on" is intended to mean "based, at least in part, on" unless explicitly stated otherwise. Also, as used herein, the term "or" is intended to be inclusive when used in a series and may be used interchangeably with "and/or," unless explicitly stated otherwise (e.g., if used in combination with "either" or "only one of").

What is claimed is:

1. An optical module comprising:

a printed circuit board; and

a flexible board,

wherein the printed circuit board includes:

an insulating base,

a first transmission line provided on the insulating base,

a first ground conductor disposed in the insulating base,

a notch portion formed on a side surface of the insulating base such that the first ground conductor is partially exposed,

a conductor provided in the notch portion and electrically connected to the first ground conductor, and

a first electrode exposed on a main surface of the insulating base facing the flexible board and electrically connected to the first transmission line,

wherein the flexible board includes:

an insulating sheet including a plurality of insulating layers,

a second transmission line provided on the insulating sheet,

a second ground conductor disposed in the insulating sheet,

a second electrode exposed on a main surface of the insulating sheet facing the printed circuit board and connected to the second transmission line, and

a third electrode exposed on the main surface of the insulating sheet facing the printed circuit board and connected to the second ground conductor,

wherein the first electrode and the second electrode are electrically connected, and

wherein the conductor and the third electrode are connected by solder.

2. The optical module of claim **1**, wherein the notch portion and the conductor constitute a castellation.

3. The optical module of claim **1**, wherein the first ground conductor is composed of a plurality of ground conductors.

4. The optical module of claim **1**, wherein the third electrode is a part of the second ground conductor exposed from the insulating sheet.

5. The optical module of claim **1**, wherein a center line of the first electrode overlaps the notch portion when viewed from a direction orthogonal to the main surface of the insulating base.

6. The optical module of claim **5**, wherein a center line of the notch portion and the center line of the first electrode do not coincide with each other when viewed from the direction orthogonal to the main surface of the insulating base.

7. The optical module of claim **5**, wherein a center line of the notch portion and the center line of the first electrode coincide with each other when viewed from the direction orthogonal to the main surface of the insulating base.

8. The optical module of claim **1**, wherein an entirety of the third electrode is disposed at a same position as the side surface or on an inner side of the printed circuit board further than the side surface in an extending direction of the insulating sheet.

9. The optical module of claim **1**, wherein the first ground conductor has an opening at a position overlapping the first electrode when viewed from a direction orthogonal to the main surface of the insulating base.

10. The optical module of claim **1**, wherein

the conductor and the third electrode are orthogonal to each other, and

the solder forms a fillet.

* * * * *